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ACTIVITY RHYTHM AND THERMOREGULATION IN THE SOUTH INDIAN FLYING LIZARD, DRACO DUSSUMIERI DUM & BIB

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IT is now fairly well-known that lizards are capable of controlling their body temperature to a certain extent by behavioral means and to a lesser extent by physiological means and that they obtain heat by direct absorption of radiant energy. Hence they are ectothermic or heliothermic. Whatever the environments they inhabit, they tend to keep a fairly constant body temperature (Bogert, 1959; Cowles and Bogert, 1944, 1946; Cole, 1943; Hirth, 1963a; Norris, 1949). Bartholomew and Tucker (1964) found that in Australian Varanids body temperature always exceeded ambient temperature and that in these respiratory movements are related to body temperature. In recent years a good amount of information is available on the temperature relations of American desert lizards (Bogert, 1949 a, b; Colbert, Cowles and Bogert, 1946; Cowles, 1941, 1958; Norris, 1958). Lee and Badham (1963) studied body temperature, activity and behaviour of the agamid, *Amphibolurus barbatus*, and Cloudsley-Thompson (1965) studied rhythmic activity and temperature relations of the diurnal skink, *Mabuya quinquetaeniatus* (Lichtenstein) and the nocturnal gecko, *Tarentola annularis* (I. Geoffroy).

One thing that struck me most while going through the literature was that most of the work on activity and thermoregulation in lizards was done with lizards living in desert or semi-arid conditions. I am not aware of any work done on temperature relations and activity patterns of lizards of the tropical rain-forests. This prompted me to carry out the present investigation of the activity patterns and thermoregulation of the South Indian Flying lizard, *Draco dussumieri*, which is a typical tropical rain forest inhabitant. This lizard is found in many parts of South West India ranging from Goa through Western Ghats to Trivandrum District (Kerala), inhabiting hilly or semi-hilly regions, with plenty of rain and luxuriant vegetation. Kerala is a rain forest region with only two seasons—summer or dry and rainy or wet with limited range of temperature variations.

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Draco dussumieri is a lizard adapted for this type of habitat. The present communication is a study of the activity patterns and temperature relations of this lizard in natural and experimental conditions. I should like to mention here that owing to the lack of modern laboratory facilities, I had to limit the present investigation mainly to simple field and laboratory observations. Nevertheless, it is hoped that the reader would find points of interest in these observations which have been made mostly under natural conditions and subjecting the animal to as little stress as possible when experimental procedures were resorted to.

MATERIAL AND METHOD

Lizards were observed in the field as well as in the laboratory conditions. Measurements of the body temperature and ambient temperature were taken throughout the day at half-an-hour interval, during all seasons of the year. Body temperature was measured by inserting, immediately after capture, a thermometer into the oesophagus. Activity patterns were studied mainly by following the lizards in the field itself. Heat tolerance, thermoregulation and lethal temperature etc. were recorded by conducting the following simple experiments:

Experiment 1: Kept the lizard in direct sunlight in the field without allowing it to escape to the shade. Body temperature, ambient temperature and behaviour were noted at regular half-an-hour intervals.

Experiment 2: Kept the lizard in direct sunlight in the field with provision to move to the shade if it wanted. Measurements were taken and behaviour noted as before.

Experiment 3: Kept the lizard in an electric oven and changes in the body temperature and activity were recorded as the temperature of the oven increased.

Experiment 4: Kept the lizard in the refrigerator and cooled gradually. Changes in the body temperature were noted and behavioral changes were also observed.

OBSERVATIONS AND CONCLUSIONS

Activity rhythm: *Draco dussumieri* is diurnal. They are inactive in the night and actually sleep. While sleeping, they remain flat on the substratum with eyes closed. Even with a gentle touch they do not awaken. But when the cage is illuminated the eyes are opened hesitatingly, the light seeming to be unpleasant.

Activity pattern during hot months: There are two periods of activity during the summer days—both during the low temperature periods, that is, betwenn 9 a.m. and 12.30 p.m. in the forenoon and between 2.30 and 4.30 in the afternoon. In the morning activity begins by 7.30 as slow movements on the tree and remains exposed to the rising sun (basking, thereby raising the body temperature). Active movements start only by 9 a.m. By 12.30 the ambient temperature goes up to 104°F. The period between 12:30 and 2.30 is the high temperature period of the day when the ambient temperature rises to 118°F. During this period of the day the animal stops movement and comes down to the main trunk of the tree or goes up to the crown of the cocoanut palm where it is cool and shady. It remains with limbs stretched to the sides and body flattened. The high environmental temperature incapacitates it completely. The colouration is cryptic and blends perfectly with the background. The lizard is, in fact, entering into a temporary 'summer sleep'. By 2.30 the ambient temperature begins to fall gradually and the second activity period commences. It wakes up from 'sleep' and starts movement. Up to 4.30 p.m. the animal remains active. After 4.30 the pace of movement slows down and finally sleeps in the night. This periodicity in activity can be seen throughout the summer months with a perfect rhythm.

Activity pattern during wet months: During wet months there are no marked fluctuations in the ambient temperature which ranges from 76° F. to 88°F. The body temperature, however, always remains 2 or 3°F. above the ambient temperature. Under these conditions behavioral pattern is different. There is no periodicity in activity as seen in the hot months and the lizard can be seen active throughout from morning till evening, with occasional basking in the sun to raise the body temperature.

Thermoregulation: The animals kept in cages in the laboratory always keep a steady temperature 1 or 2°F. above the room temperature. The body temperature rises as the room temperature rises and it falls as the room temperature falls. From evening to next day morning (during night) the body temperature will be more or less equal to the room temperature.

Experiment 1: With the rise in ambient temperature the body temperature also rose. Upto 97.5°F. the animal was quite active and showed no discomfort. The normal activity range of temperature was 79° F. to 97.5°F., the latter being the optimal maximum body temperature. But when the body temperature exceeded this, the lizard began panting.

The high environmental temperature completely incapacitates *Draco dussumieri* and it tries to maintain the body temperature at the optimal maximum by shade-seeking. Inger (1959) found that *Mabuya rudis* is active during the heat of the day, while *Sphenomorphus sabanus* at dawn and dusk. *Cnemidophorus sexlineatus* is active only when the sand has been warmed up by the sun (Barden, 1942). Cloudsley-Thompson (1965) observed that in *Mabuya quinquetaeniatus* and *Tarentola annularis*, activity was much reduced at lower temperatures; activity appeared to be far more temperature dependent in *Mabuya quinquetaeniatus* than in *Tarentola annularis*. *Mabuya quinquetaeniatus* showed much more activity at higher temperatures than did *Tarentola annularis*. His experimental results made it clear that both these lizards have strong endogenous diurnal rhythms of activity.

Bartholomew and Tucker (1964) found that in Australian varanids body temperature always exceeded ambient temperature. They also noted that in these, respiration is related to body temperature. When body temperature was below 35° C. inspiration was slow, but when the body temperature exceeded 38° C. this pattern changed to powerful gular pumping motions at an accelerated rate which according to them were the functional equivalent of panting. In *Draco dussumieri* also the body temperature is always maintained above the ambient temperature except in the night, early morning and evening when the body temperature coincides with the ambient temperature. But on hot summer days the body temperature at which the lizard is quite comfortable and active is between 79° F. and 97.5° F. Under natural conditions in summer, the animal does not allow the body temperature to go above this. This is done by the periodicity in activity. But a higher body temperature up to 102° F. is tolerated by panting. George and Shah (1965) suggested that in reptiles, lung is thermoregulatory. In *Draco dussumieri*, as observed in *Draco maculatus* by George and Shah, the lung is provided with a pair of semi-saccular extensions from the antero-lateral region extending into the shoulder region and also an extensive saccular part which extends to almost the posterior end of the abdominal cavity. This structural modification of the lung and the panting behaviour of the lizard at temperature above the optimal maximum support their suggestion. Further, Brattstrom (1965) presented data on the body temperatures of a number of reptiles living in different habitats and showed that in these animals respiratory water loss is an effective method of cooling the body. The desert iguana

in *Draco dussumieri* is a means of regulating the body temperature in the hot summer days. Norris (1953) showed that the desert iguana manages to live under conditions above 50° C. by intermittent activity and frequent resorting to shade and burrows. *Draco dussumieri* also maintains a steady body temperature by this kind of intermittent activity and shade seeking at high ambient temperatures. In this context, it is interesting to note that in the case of the Nile crocodile, *Crocodilus niloticus L.*, there are two basking periods: between 07.00 and 09.30 hours and between 14.30 and 17.30 hours, and in the heat of the day there is a secondary return to the water or into the shade (Cott, 1961). Comparable results were obtained by Cloudsley-Thompson (1964) from his simple aktograph measurements on the same animal. His experiments showed that the Nile crocodile exhibits a weak diurnal rhythm of activity. In the case of the lizard *Amphibolurus barbatus* activity between 30 and 40° C. is relatively uniform (Lee and Badham, 1963). The highest rates of activity occurred above 40° C., but this was due to the lizards seeking shade almost immediately when their body temperature reached this level (Lee and Badham, 1963). They also found that in *Amphibolurus barbatus*, though most of the activity is restricted to the preferred range, certain behaviours such as feeding and threat display are relatively independent of the preferred temperatures. This contrasts with the present observations on *Draco dussumieri* where these behavioral patterns are dependent on the preferred temperatures. Similar results were obtained by Cowles and Bogert (1944) in *Sceloporus m. magister* and by Norris (1953) in *Dipsosaurus dorsalis*.

The exactness with which *Draco dussumieri* commences and stops activity is so striking that one is apt to suggest the existence of an 'endogenous rhythm' or 'clock' which is temperature-dependent, operative in its activity. In recent years considerable evidence has accumulated to show that the pineal body in reptiles is concerned with thermoregulation. It has been found (Stebbins, 1957; Stebbins and Eakin, 1958) that surgical removal of the pineal eye from lizards of several species *Sceloporus occidentalis, S. undulatus, Uta stansburiana* and *Uma inornata*) caused a significant extension of the duration of the daily periods which they spent exposed to sunlight but did not alter the range of body temperatures, characteristic of normal activity.

In *Draco dussumieri* the pineal complex is well-developed and I believe that it has some influence on the characteristic activity rhythm in this lizard. Confirmative evidence has yet to come from further studies.

Above 100°F. panting was accentuated and the respiratory rate was on the increase, it being 54 per minute. At 102°F. the lizard collapsed and succumbed. At that period the ambient temperature was 104°F. This experiment shows that the optimal maximum body temperature is 97.5°F., and up to 102°F. it can tolerate by panting and 102°F. is the lethal body temperature. These results have been confirmed by repeating the experiment at least six times.

Experiment 2: Even when the ambient temperature went beyond the optimal maximum, no considerable panting could be noticed. The lizard moved to the shade. The body temperature was maintained at the optimal maximum. This is exactly what the lizard does in the hot summer days when the body temperature tends to surpass this optimal maximum. So the peculiar periodicity in activity shown by this lizard during summer is for thermoregulation.

Experiment 3: The results of this experiment confirmed the results of the first experiment. With the increase in temperature of the oven, the body temperature also rose. The animal was active and normal in behaviour upto 97.5°F. Beyond this the lizard began panting. At 102°F. the lizard collapsed. The temperature of the oven had reached 104°F. at that time.

Experiment 4: When the temperature was lowered beyond the room temperature, the body temperature was also lowered correspondingly, and the activity was slackened. As the cooling progressed, the lizard became more and more torpid and it turned dark in colour. But when taken out and brought to room temperature, in a few minutes, it lost its torpidity and began to move about. Cooling below 6° C. was found to be lethal and the body temperature was 66° F. Results of this experiment indicate that rate of cooling is slow.

DISCUSSION

Diurnal or Circadian rhythm of activity is of great significance to reptiles since they are ectothermic. Park (1938) studied diurnal activity patterns of *Mabuya mabuya*, *Basiliscus basiliscus* and *Anolis frenatus*. Kayser and Marx (1951) found that *Lacerta agilis* and *Lacerta muralis* are active between 10.00 and 16.00 hours. Field observations and simple experiments in the laboratory show that in *Draco dussumieri* there are two activity periods in summer days and this activity rhythm is dependent on the environmental temperatures. This behavioral rhythm or periodicity

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REFERENCES

Barden, A. 1942. Activity of the lizard, Chemidophorus Sexlineatus. *Ecology* 23 : 336-344.

Bartholomew, G. A. 1959. Photoperiodism in Reptiles. Photoperiodism and related phenomena in plants and animals. American Association for the Advancement of Science, Washington, D.C. 669-676.

Bartholomew, G. A. and Tucker, V. A. 1963. Control of changes in body temperature, metabolism, and circulation by the agamid lizard, Amphibolurus barbatus. *Physiol. Zool.*, 36 : 199-218.

Bartholomew, G. A. and Tucker, V. A. 1964. Size, Body temperature, thermal conductance, Oxygen consumption, and heart rate in Australian Varanid lizards. *Physiol. Zool.*, 37 : 341-354.

Bogert, C. M. 1949a. Thermoregulation in reptiles, a factor in evolution. *Evolution* 3: 195-211.

Bogert, C. M. 1949b. Thermoregulation and eccritic body temperatures in Mexican lizards of the genus Sceloporus. *Arm. Inst. Biol. Univ. Nacion. Mexico,* 20: 415-426.

Bogert, C. M. 1959a. How reptiles regulate their body temperature. *Sci. Am.* 200: 105-120.

Brattstrom, B. H. 1965. Body temperatures of reptiles. *Am. Midl. Nat.* 73: 376-422.

Cloudsley-Thompson, J. L. 1961. Rhythmic activity in animal physiology and behaviour. New York & London: Academic Press.

Cloudsley-Thompson, J. L. 1964. Diurnal Rhythm of activity in the Nile crocodile. *Anim. Behav.* 12: 98-100.

Cloudsley-Thompson, J. L. 1965. Rhythmic activity, temperature tolerance, water relations and mechanism of heat death in a tropical skink and gecko. *J. Zool.* 146: 55-69.

Cole, L. C. 1943. Experiments on toleration of high temperature in lizards with reference to adaptive coloration. *Ecology*, 24: 94-108.

Colbert E. M., Cowles, R. B. and Bogert, C. M. 1946. Temperature tolerances in the American alligator and their bearing on the habits, evolution, and extinction of the dinosaurs. *Bull. Am. Mus. Nat. Hist.* 86: 327-374.

Cott, H. B. 1961. Scientific results of an enquiry into the ecology and economic status of the Nile crocodile, (Crocodilus niloticus) in Uganda and Northern Rhodesia. *Trans. Zool. Soc. Lond.*, 29(4): 211-356.

Cowles, R. B. 1955. Notes on natural history of a South African agamid lizard. *Herpetologica*, 12 : 297-302.

Cowles, R. B. and Bogert, C. M. 1944. A preliminary study of the thermal requirements of desert reptiles. *Bull. Am. Mus. Nat. Hist.* 83: 261-296.

Cowles, R. B. and Bogert, C. M. 1947. Temperature of desert reptiles. *Science*, 105: 282.

Dawson, W. R. and Bartholomew, G. A. 1958. Metabolic and cardiac responses to temperature in the lizard Dipsosaurus dorsalis. *Physiol. Zool.* 31: 100-111.

George, J. C. and Shah, R. V. 1965. Evolution of air sacs in Sauropsida. *J. Anim. Morphol. Physiol.* 12: 255-263.

Heath, J. E. 1962. Temperature regulation and diurnal activity in horned lizards. U.C.L.A. Archives Thesis No. 2208 ; 135 pp.

Hirth, H. F. 1963a. The ecology of two lizards on a tropical beach. *Ecol. Monogr.* **33**: 83-112.

Hirth, H. F. 1963b. Some aspects of the natural history of Iguana iguana on a tropical strand. *Ecology*, **44**: 613-615.

Inger, R. F. 1959. Temperature responses and ecological relations of two Bornean lizards. *Ecology*, 40: 127-136.

Kayser, Ch. and Marx, Ch. 1951. Le rhythme nycthémeral de 1' activité et la memoire du temps chez le lézard (*Lacerta agilis et Lacerta muralis*). *XX Congr. int. Philos. Sci. Paris*, 1949, 6 (Biol.): 96-103.

Lee, A. K. and Badham, J. A. 1963. Body temperature, Activity, and Behaviour of the Agamid Lizard, Amphibolurus barbatus. *Copeia*, 387-394.

Smith, M. A. 1935. "Reptilia and Amphibia: Sauria" Fauna of Brit. India Series.

Norris, K. S. 1949. Observations on the habits of the horned lizard Phrynosoma m'caili. *Copeia*, 176-180.

Norris, K. S. 1953. The ecology of the desert iguana Dipsosaurus dorsalis. *Ecology*, **34**: 265-287.

Norris, K. S. 1958. The evolution and systematics of the iguanid genus Uma and its relation to the evolution of other North American desert reptiles. *Bull. Am. Mus. Nat. Hist.* **114**: 249-326.

Park, O. 1938. Studies in nocturnal ecology VII. Preliminary observations in Panama rain Forest animals. *Ecology*, **19**: 208-223.

Richards, P. W. 1964. The tropical rain forest, an ecological study. Cambridge University Press.

Ruibal, R. 1961. Thermal relations of five species of tropical lizards. *Evolution*, **15**: 98-111.

Stebbins, R. C. 1957. Studies of pineal function in lizards *Anat. Rec.* **128**: 628-629.

Stebbins, R. C. and Eakin, R. M. 1958. The role of the "third eye" in reptilian behaviour. *Am. Museum Novitates*, No. 1870, 1-40.

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